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What Are the Demographic and Radiographic Characteristics of Patients With Symptomatic Extraarticular Femoroacetabular Impingement?

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Abstract

Background Extraarticular femoroacetabular impingement (FAI) can result in symptomatic hip pain, but preoperative demographic, radiographic, and physical examination findings have not been well characterized.

Questions/purposes The purposes of this study were to (1) define the demographic characteristics of patients with symptomatic extraarticular FAI; and (2) identify relevant radiographic and physical examination findings that are associated with intraoperative locations of extraarticular FAI.

Methods For purposes of this study, we defined extraarticular FAI as abnormal contact between the extraarticular regions of the proximal femur (greater trochanter, lesser trochanter, extracapsular femoral neck) and the ilium or ischium. The diagnosis was suspected preoperatively, but it was confirmed at the time of surgery by direct visualization of extraarticular impingement after surgical hip dislocation. A prospective single-center hip preservation registry was used to retrospectively characterize patients presenting between October 2010 and November 2013 with symptomatic hip pain and intraoperative findings of extraarticular FAI (N = 75 patients, 86 hips). Detailed demographic data were recorded. Radiographs, CT, and MRI scans were reviewed for all patients by two of the authors (BFR, ELS). Outcome instruments including modified Harris hip score (mHHS), Hip Outcome Score (HOS), and International Hip Outcome Tool (iHOT-33) were assessed preoperatively. A comparison group of all patients (N = 1690 patients, 1989 hips) undergoing surgery for intraarticular FAI over the study period were included for demographic comparisons. Cases with extraarticular FAI accounted for 4% (75 of 1765 patients) of our cohort over the study time period.

Results Patients with extraarticular FAI were more likely to be younger (mean ± SD, 24 ± 7 years versus 30 ± 11 years; difference [95% confidence interval {CI}], −7 [−9 to −4]; $p < 0.001$), female (85% versus 49%; odds ratio [95% CI], 6 [3 to 12]; $p < 0.001$), to have undergone prior hip surgery (44% versus 10%; odds ratio [95% CI], 9 (6 to 15); $p < 0.001$), and have lower preoperative outcome scores after adjustment for age, sex, and revision status (mHHS 55 ± 15 versus 63 ± 15; adjusted difference [95% CI], −4 (−8 to −1); $p = 0.017$; HOS ADL 64 ± 19 versus 73 ± 18; adjusted

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.
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difference [95% CI], -7 (-11 to -3); $p = 0.002$) than patients undergoing surgery for intraarticular FAI. Within the extraarticular FAI group, preoperative femoral version on CT was different among patients with anterior versus posterior extraarticular impingement (median [first quartile, third quartile], 8° [2, 18] versus 21° [20, 30], respectively; $p = 0.005$) and anterior versus complex extraarticular impingement (median [first quartile, third quartile], 8° [2, 18] versus 20° [10, 30], respectively; $p = 0.007$]. Preoperative external rotation in extension was increased in patients with anterior versus complex extraarticular FAI (median [first quartile, third quartile], 70° [55, 75] versus 40° [20, 60]; $p < 0.001$).

Conclusions Extraarticular FAI is an uncommon source of impingement symptoms. We suspect the diagnosis often is missed, because many of these patients had prior hip surgery before the procedure that diagnosed the extraarticular impingement source. This diagnosis seems more common in younger, female patients. Radiographic and physical examination findings correspond to locations of intraoperative extraarticular impingement. Future studies will need to determine whether surgical treatment of extraarticular impingement pathology improves pain and function in this subset of patients.

Level of Evidence Level III, therapeutic study.

Introduction

Femoroacetabular impingement (FAI) results from abnormal contact between the femoral head and neck with the acetabular rim [7, 13]. These pathologic hip mechanics can injure the labral/chondral junction and potentially cause early osteoarthritic changes in the hip [32]. Both arthroscopic and open surgical hip dislocation approaches to address labral injury and contour the femoral head-neck junction and acetabular rim have resulted in improved clinical outcomes in patients with symptomatic FAI [5, 6, 17, 19, 21, 23]. Despite the widespread adoption and success of these treatments for FAI, a subset of patients fails to improve after surgery, suggesting that unaddressed sources of impingement may exist.

Extraarticular FAI results from abnormal contact between the extraarticular regions of the proximal femur (greater trochanter, lesser trochanter, extracapsular femoral neck) and the ilium or ischium [1, 2, 7, 10, 11, 14, 22, 25, 29–31]. Potential areas of contact on the pelvis include the ischium, ilium, anteroinferior iliac spine (AIIS), and acetabular rim [2, 8, 10, 12, 22, 25, 29]. Extraarticular FAI may result in pain attributable to direct compression of soft tissue structures or indirectly through the creation of abnormal stresses across the femoroacetabular articulation or impingement-induced instability [2, 22, 25, 30]. This may lead to intraarticular pathology such as labral tears and cartilage degeneration commonly seen in cam and pincer FAI. Traditional intraarticular FAI has been well characterized as a source of hip pain; however, clinical and radiographic descriptions of extraarticular FAI as a source of hip pain are limited to radiographic studies and small case series [1, 8–10, 14, 20, 22, 25, 29–31].

The purposes of this study were to evaluate a cohort of patients undergoing surgery for extraarticular FAI at a single urban tertiary referral center to (1) define the demographic characteristics of patients with extraarticular FAI; and (2) identify relevant radiographic and physical examination findings that are associated with intraoperative locations of extraarticular FAI.

Patients and Methods

This retrospective study used records from a prospectively maintained single-institution urban tertiary referral hip preservation registry. All patients undergoing hip preservation surgery including hip arthroscopy, periacetabular osteotomy, femoral osteotomy, and surgical hip dislocation are entered in the database from the practices of four surgeons (ELS, BTK, AR, SC) performing hip preservation procedures at our institution. This study included patients whose procedures took place between October 2010 and November 2013 (beginning of this study). Registry data were reviewed for 2075 total hip preservation procedures in 1765 patients treated for FAI performed over the study period (Fig. 1). Two cohorts were used for demographic comparisons: the extraarticular FAI cohort and a comparison group consisting of all patients undergoing surgery for intraarticular FAI over the same study period.

The presumptive diagnosis of symptomatic extraarticular FAI was made preoperatively based on history, physical examination, and radiographic studies. Factors that increased clinical suspicion of extraarticular FAI included lateral or posterior pain on history, poor external rotation, poor internal rotation with no evidence of a cam lesion, absence of major pelvic and acetabular deformity, a positive posterior impingement sign, incomplete response to intraarticular injection of a local anesthetic and/or corticosteroid, or continued impingement-type symptoms of FAI after arthroscopic treatment without a residual cam lesion. After failure of conservative management including injection, activity modification, and physical therapy directed by our center's therapists, surgical intervention was recommended. The diagnosis of extraarticular FAI was confirmed intraoperatively through direct visualization of extraarticular contact between the greater or lesser trochanter and the ilium/ischium within a physiologic ROM through an open surgical approach. Physiologic ROM was defined as impingement visualized before 90° of hip

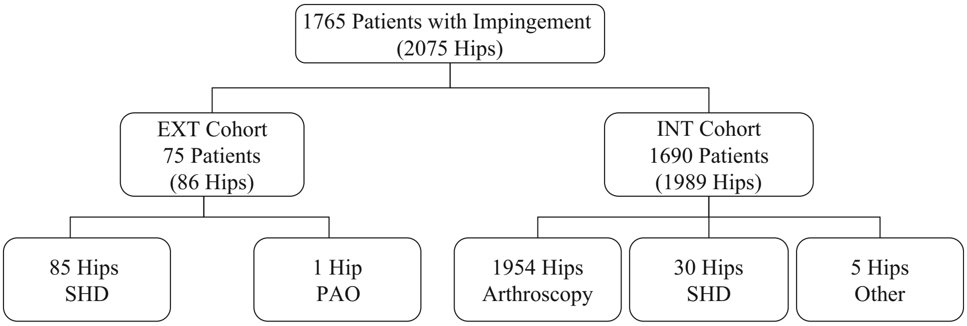

Fig. 1 Flow diagram outline of the extraarticular (EXT) impingement cohort and a comparison cohort of patients with exclusively intraarticular (INT) impingement is shown. SHD = surgical hip dislocation; PAO = periacetabular osteotomy.

Table 1. Demographic comparison of patients undergoing surgery for extraarticular and intraarticular FAI

Demographics	Patients with extraarticular FAI (N = 75)	Patients with intraarticular FAI (N = 1690)	Difference in means or odds ratio (95% CI)	p value
Age (years, mean ± SD)	24 ± 7	30 ± 11	−7 (−9 to −4)	< 0.001*
Female (%)	85	49	6 (3 to 12)	< 0.001*
Laterality (% right side)	57	57	1 (1 to 1)	0.904
Previous surgery (%)	44	10	9 (6 to 15)	< 0.001*

* $p < 0.05$; FAI = femoroacetabular impingement; CI = confidence interval.

flexion, internal rotation of 30° in hip flexion, external rotation of at least 45° in flexion, and 30° in extension.

All patients undergoing surgery for extraarticular FAI documented at the time of surgery were included in this study (N = 75 patients, 86 hips) (Fig. 1). Average age was 24 ± 7 years and laterality was similar between left and right hips (Table 1). Exclusion criteria included patients without documented extraarticular FAI or failure to consent for inclusion in the registry. The majority of patients underwent a surgical hip dislocation approach to treat their extra- and intraarticular FAI (Fig. 1). An intraarticular FAI cohort served as a comparison group for demographic data. For the intraarticular FAI group, all patients undergoing hip preservation surgery for intraarticular FAI were included (N = 1690 patients, 1989 hips) (Fig. 1). Exclusion criteria included a diagnosis other than FAI. The majority of intraarticular FAI cases at our institution are treated by hip arthroscopy (Fig. 1). Institutional review board approval was obtained before this study.

Demographic data including age, sex, laterality, and previous hip/pelvic surgery were recorded for each patient, and these data were compared between the extraarticular and intraarticular FAI cohorts. Medical history, procedures performed during surgery, and postoperative complications were recorded for patients undergoing surgery for extraarticular FAI. Complications were graded using the validated modified Dindo-Clavien grading scale [24].

For radiographic and preoperative ROM assessments, a more detailed assessment of the extraarticular FAI group was performed by dividing this cohort into three different types of observed extraarticular FAI pathology that were recorded at the time of surgery. Type I extraarticular FAI was described as anterior facet of the greater trochanter or intertrochanteric line on the anterior acetabular rim and/or AIIS (Fig. 2A). Type II extraarticular FAI was described as posterolateral impingement of the greater trochanter or extraarticular femoral neck on the ischium (Fig. 2B). Type III extraarticular FAI represented complex impingement of the greater trochanter and/or extraarticular femoral neck in both anterior and posterior locations on the ilium and/or ischium (Fig. 2C).

Detailed radiographic and physical examination data were compared among these three subgroups in the extraarticular FAI cohort by two of the authors (BFR, ELS). Physical examination data including hip ROM and AP impingement signs were recorded at the time of preoperative examination by the operating surgeon (ELS). For radiographic data, plain radiographs, three-dimensional (3-D) CT scan, and MRI were examined when available for each patient. Lateral center-edge angle (LCEA) and Tönnis grade were measured in a standard fashion on AP pelvis radiographs. CT scans with 3-D reconstruction were used to measure femoral version; acetabular version at 1 o'clock, 2 o'clock, and 3 o'clock; maximum alpha angle; and femoral

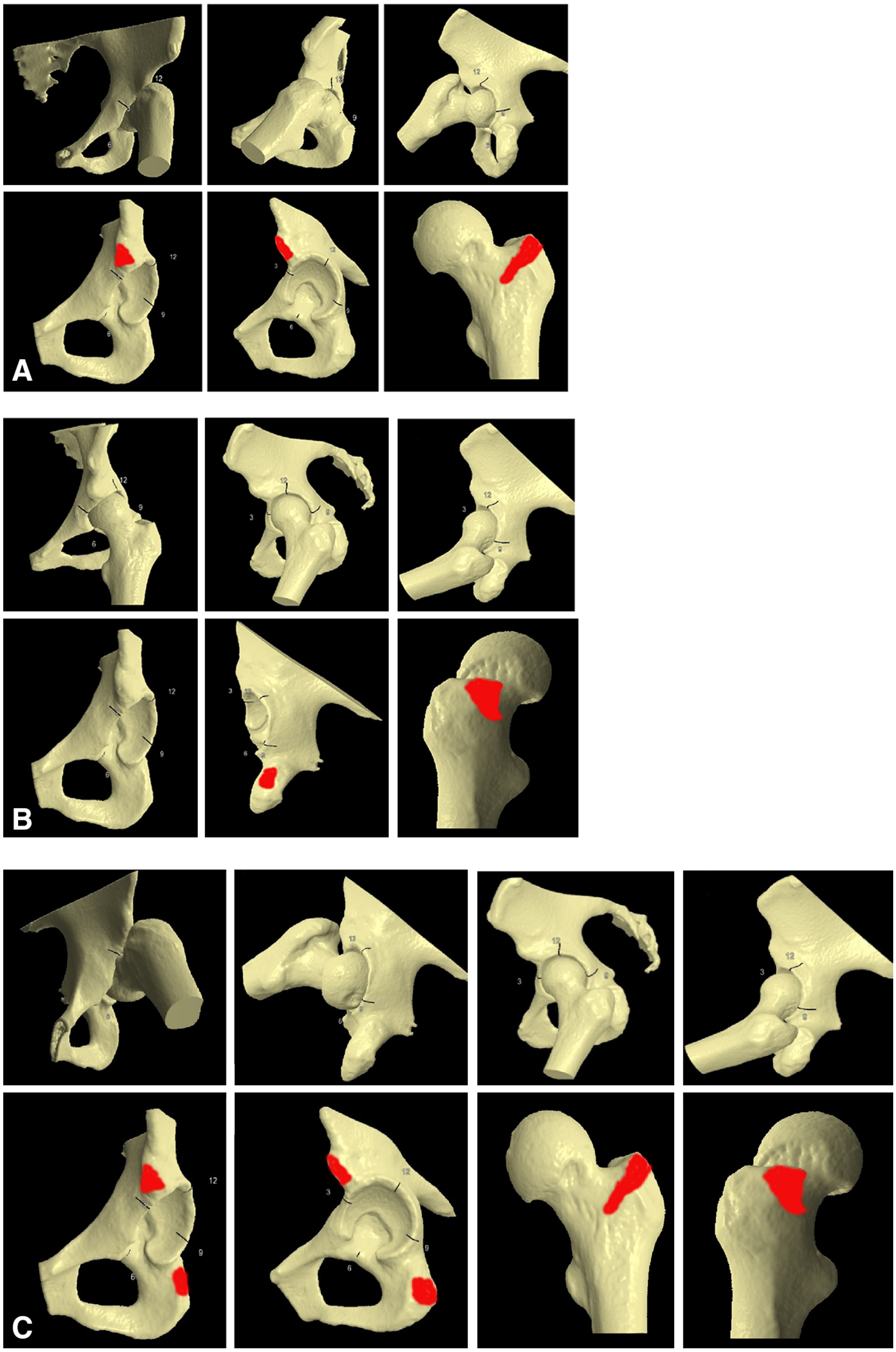

Fig. 2A–C Description of observed patterns of extraarticular FAI with associated radiographic and physical examination findings is shown. (**A**) Anterior (Type I) extraarticular FAI: anterior facet of the greater trochanter or intertrochanteric line on the anterior acetabular rim and/or AIIS; summary radiographic and physical examination features include relative femoral retroversion on CT and relative decreased internal rotation at 90° of hip flexion and relative increased external rotation at 0° and 90° of hip flexion. (**B**) Posterior (Type II) extraarticular FAI: posterolateral impingement of the greater trochanter or extraarticular femoral neck on the ischium; summary radiographic and physical examination features include relative femoral anteversion on CT and relative increased internal rotation at 90° of hip flexion. (**C**) Complex (Type III) extraarticular FAI: impingement of the greater trochanter and/or extraarticular femoral neck in multiple locations both anterior and posterior on the ilium and/or ischium; summary radiographic and physical examination features include relative femoral anteversion on CT and relative decreased internal rotation at 90° of hip flexion and relative decreased external rotation at 0° and 90° of hip flexion.

neck-shaft angle to provide a more detailed analysis of the proximal femoral and acetabular geometry with measurements performed as previously described [3, 13]. Presence of a cam lesion was defined by an alpha angle greater than 50° [13]. Presence and location of a labral tear were identified from MRI scans. All radiographic measurements were performed using the hospital-based Picture Archiving and Communications Software system (Sectra AB, Linkoping, Sweden). CT and MRI evaluations were performed and documented by one of eight fellowship-trained musculoskeletal radiologists blinded to the details of the study with extensive experience in examining CT and MRI for preoperative planning in hip preservation surgery [3, 12, 13]. The operating surgeon performed and documented plain radiographic measurements.

Statistical Methods

Statistical analyses were performed by members of the research team with advanced training in biostatistics (PDF, KGF) using SAS Version 9.3 (SAS Institute, Cary, NC, USA). Continuous variables are presented as means and SDs or medians and first and third quartiles for normally and nonnormally distributed data, respectively. Categorical variables are presented as counts and percentages. Continuous variables were compared between the extraarticular and intraarticular FAI groups using independent sample t-tests and presented as differences in means with 95% confidence intervals (CIs). Preoperative survey scores were further compared between extraarticular and intraarticular FAI groups after adjustment for age, sex, and revision status using multiple regression. Categorical variables were compared between the extraarticular and intraarticular FAI groups using chi square or Fisher's exact tests, as appropriate, with effect size presented as odds ratios with 95% CIs. Continuous variables were compared between extraarticular FAI types using Kruskal-Wallis tests. If $p < 0.05$ using the Kruskal-Wallis test, types were compared in a pairwise fashion using Wilcoxon rank-sum tests with differences presented as Hodges-Lehmann estimates of location shift with 95% CIs. Binary variables were compared between extraarticular FAI types using chi square or Fisher's exact tests, as appropriate, and categorical ordinal variables were compared using cumulative logit models. If $p < 0.05$ for the three-group comparison, types were compared in a pairwise fashion using the same methods with effect size presented as odds ratios (ORs) with 95% CIs. Probability values and CIs associated with pairwise comparisons between extraarticular FAI types were adjusted for multiple comparisons by the Bonferroni method. All comparative analyses were two-sided and p values < 0.05 were considered statistically significant.

Results

Patient Demographics

Patients undergoing surgery for FAI were younger in the extraarticular FAI group relative to the intraarticular FAI group (mean ± SD, 24 ± 7 years versus 30 ± 11 years; difference [95% CI], −7 [−9 to −4]; $p < 0.001$) (Table 1). An increased proportion of female patients was present in the extraarticular FAI group relative to the intraarticular FAI group (85% versus 49%; OR [95% CI], 6 [3 to 12]; $p < 0.001$) (Table 1). Laterality was similar in both groups (57% affected right hip in both groups) (Table 1). Patients with extraarticular FAI were more likely to have undergone previous hip surgery than the intraarticular FAI cohort (44% versus 10%; OR [95% CI] 9 [6 to 15]; $p < 0.001$) (Table 1). Preoperative outcome scores for modified Harris hip score (mHHS) and Hip Outcome Score activities of daily living (HOS ADL) were lower in the extraarticular FAI cohort than the intraarticular FAI cohort after adjustment for age, sex, and revision status (mHHS 55 ± 15 versus 63 ± 15; adjusted difference [95% CI] −4 [−8 to −1]; $p = 0.017$; HOS ADL 64 ± 19 versus 73 ± 18; adjusted difference [95% CI] −7 [−11 to −3]; $p = 0.002$; Table 2). Previous disease processes aside from FAI affecting the hip had been diagnosed in 16% of patients (Table 3). This included Legg-Calvé-Perthes (N = 7), developmental dysplasia of the hip (N = 2), slipped capital femoral epiphysis (N = 1), Ehlers-Danlos (N = 1), and postinfectious deformity (N = 1). Previous hip surgery in the extraarticular FAI cohort included hip arthroscopy (N = 24) and pelvic osteotomy (N = 6) (Table 3).

In patients undergoing surgery for extraarticular FAI, procedures performed intraoperatively included anterior trochanteric osteoplasty (N = 43 [50%]), posterior trochanteric osteoplasty (N = 12 [14%]), combined anterior and posterior osteoplasty (N = 20 [22%]), and relative neck lengthening (N = 18 [23%]) (Table 4). Concomitant intraarticular FAI was common in the extraarticular FAI cohort and osteochondroplasty at the anterior or anterior/lateral head and neck junction was performed in all patients. Labral repair (N = 37 [43%]), labral reconstruction (N = 3 [4%]), rim resection (N = 35 [41%]) were performed in a subset of patients when necessary (Table 4).

Radiographic and Physical Examination Characteristics of Extraarticular FAI

Three general types of extraarticular FAI based on locations of contact between the femur and pelvis were observed intraoperatively as described previously: Type I (anterior), Type II (posterior), and Type III (complex)

Table 2. Preoperative outcome scores for patients undergoing surgery for extraarticular and intraarticular FAI

Preoperative survey score	Patients with extraarticular FAI (N = 75)	Patients with intraarticular FAI (N = 1690)	Unadjusted difference (95% CI)	p value	Adjusted difference† (95% CI)	p value
mHHS (mean ± SD) (N = 68, N = 1349)	55 ± 15	63 ± 14	−8 (−12 to −4)	< 0.001*	−4 (−8 to −1)	0.017*
HOS ADL (mean ± SD) (N = 67, N = 1365)	64 ± 19	73 ± 18	−10 (−15 to −6)	< 0.001*	−7 (−11 to −3)	0.002*
HOS sport (mean ± SD) (N = 67, N = 1341)	46 ± 26	52 ± 25	−6 (−12 to 0)	0.053	−2 (−8 to 5)	0.573
iHOT-33 (mean ± SD) (N = 63, N = 1039)	32 ± 18	41 ± 19	−8 (−13 to −4)	< 0.001*	−4 (−9 to 1)	0.086

* p < 0.05; †differences in means are adjusted for age, sex, and revision status; FAI = femoroacetabular impingement; CI = confidence interval; mHHS = modified Harris hip score; HOS = Hip Outcome Score; ADL = activities of daily living; iHOT-33 = International Hip Outcome Tool.

Table 3. Previous diagnoses related to hip pathology and procedures performed

Previous hip diagnoses and procedures	Patients with extraarticular FAI (N = 75)
Previous hip diagnoses (%)	12 (16%)
Legg-Calvé-Perthes	7
DDH	2
Slipped capital femoral epiphysis	1
Ehlers-Danlos	1
Sequelae of septic hip	1
Previous surgery	
Hip arthroscopy	24
Pelvic osteotomy	6
Miniopen OC	1
CRPP	1
Femoral osteotomy	1
Sports hernia repair	1
Other	1

FAI = femoroacetabular impingement; DDH = developmental dysplasia of the hip; OC = osteochondroplasty; CRPP = closed reduction percutaneous pinning.

Table 4. Procedures performed intraoperatively during surgery for extraarticular FAI

Procedures performed	N = 86 hips (%)
Anterior trochanteric osteoplasty	43 (50)
Posterior trochanteric osteoplasty	12 (14)
Combined anterior/posterior osteoplasty	20 (22)
Relative neck lengthening	18 (23)
Osteochondroplasty	85 (99)
Acetabular rim resection	35 (41)
Labral repair	37 (43)
Labral reconstruction	3 (4)

FAI = femoroacetabular impingement.

(Fig. 2A–C). Patients with anterior extraarticular FAI displayed greater relative femoral retroversion versus posterior extraarticular FAI (median [first quartile, third quartile], 8° [2, 18] versus 21° [20, 30], respectively; location shift [95% CI], −16 [−26 to −4]; p = 0.005) and versus complex extraarticular impingement (20° [10, 30]; location shift [95% CI], −10 [−18 to −2]; p = 0.007) (Table 5). More advanced Tönnis grade changes were present in complex versus anterior extraarticular FAI (25% versus 2% of hips Tönnis Grade 2; OR [95% CI] 3 [1 to 10]; p = 0.039; Table 5). Other independent variables in anterior, posterior, and complex extraarticular FAI including acetabular version (median [first quartile, third quartile], one o'clock: −3° [−10, 5], 7° [−3, 17], −1° [−7, 9], respectively, p = 0.199; two o'clock: 6° [0, 14], 18° [9, 20], 11° [2, 18], respectively, p = 0.122; three o'clock 15° [10, 18], 20° [16, 23], 16° [12, 21], p = 0.079), alpha angle (median [first quartile, third quartile], 60° [46, 65], 48° [34, 56], 49° [44, 68], respectively, p = 0.388), neck-shaft angle (median [first quartile, third quartile], 132° [127, 135], 133° [124, 136], 134° [130, 136], respectively, p = 0.722), and LCEA (median [first quartile, third quartile], 31° [28, 37], 35° [33, 35], 33° [29, 37], respectively, p = 0.833) were not different between groups (Table 5). In anterior, posterior, and complex extraarticular FAI groups, presence of a cam lesion (51%, 29%, and 42%, respectively, p = 0.524) or labral tear (67%, 67%, 43%, respectively, p = 0.219) was not significantly associated with extraarticular FAI type (Table 5).

With respect to physical examination, external rotation in extension was increased between patients with anterior

Table 5. Radiographic parameters in three patterns of observed extraarticular FAI

Radiographic parameter CT scan	Type I (anterior) N = 41	Type II (posterior) N = 7	Type III (complex) N = 24	p value
Acetabular version (°)				
One o'clock	−3 (−10, 5)	7 (−3, 17)	−1 (−7, 9)	0.199
Two o'clock	6 (0, 14)	18 (9, 20)	11 (2, 18)	0.122
Three o'clock	15 (10, 18)	20 (16, 23)	16 (12, 21)	0.079
Femoral version (°)	8 (2, 18)†	21 (20, 30)†	20 (10, 30)†	< 0.001*
Alpha angle (°)	60 (46, 65)	48 (34, 56)	49 (44, 68)	0.388
Cam lesion (%)	51	29	44	0.524
Femoral neck-shaft angle (°)	132 (127, 135)	133 (124, 136)	134 (130, 136)	0.722
Radiograph	N = 47	N = 9	N = 28	
Labral tear (%)				
Yes	67	67	43	0.219
No	27	22	36	
Diffuse degeneration	7	11	21	
Tönnis grade (%)				
0	68‡	67	46‡	0.039*
1	30‡	33	29‡	
2	2‡	0	25‡	
Lateral center-edge angle (°)	31 (28, 37)	35 (33, 35)	33 (29, 37)	0.833

All continuous variables presented as median (first quartile, third quartile); *$p < 0.05$; †$p = 0.005$ for anterior versus posterior extraarticular FAI, $p = 0.007$ for anterior versus complex extraarticular FAI; ‡$p = 0.039$ for anterior versus complex extraarticular FAI; FAI = femoroacetabular impingement.

versus complex extraarticular FAI (median [first quartile, third quartile] 70° [55, 75] versus 40° [20, 60]; location shift [95% CI], −25 [−40 to −10]; $p < 0.001$) (Table 6). Preoperative external rotation at 90° of hip flexion was increased between patients with anterior versus complex extraarticular FAI (median [first quartile, third quartile], 60° [45, 70] versus 40° [20, 50]; location shift [95% CI], 20 [−30 to 10]; $p < 0.001$) (Table 6). Preoperative internal rotation at 90° was increased with posterior relative to both anterior and complex extraarticular FAI (median [first quartile, third quartile], 40° [30, 55] versus 15° [10, 20] and 15° [10, 30], respectively; location shift [95% CI], 25 [10 to 40] and 25 [5 to 40], respectively; $p < 0.001$ and 0.018, respectively) (Table 6). Other independent variables in the three groups including presence of anterior (100%, 88%, and 93%, respectively, $p = 0.056$) and posterior (50%, 75%, and 75%, respectively, $p = 0.113$) impingement signs, internal rotation in extension (median [first quartile, third quartile], 15° [5, 30], 40° [15, 48], 15° [5, 33], respectively, $p = 0.058$), hip flexion (median [first quartile, third quartile], 95°[90, 95], 100° [98, 103], 95° [90, 100], respectively, $p = 0.138$), and abduction (median [first quartile, third quartile], 25° [20, 30], 30° [18, 33], 25° [15, 30], respectively, $p = 0.532$) were not significantly different between groups (Table 6).

Discussion

Intraarticular FAI resulting from abnormal contact between the femoral head and/or neck with the acetabular rim has been well characterized as a source of mechanical hip pain. Extraarticular FAI, however, has not been well characterized, and studies of the demographic, radiographic, and clinical outcomes for patients undergoing surgery for symptomatic extraarticular FAI are isolated to case reports and limited case series [1, 2, 8, 10, 11, 14, 20, 22, 25, 28–31]. The purposes of this study were to evaluate a cohort of patients undergoing surgery for extraarticular FAI at a single urban tertiary referral center to (1) define the demographic characteristics of patients with extraarticular FAI; and (2) identify relevant radiographic and physical examination findings that predict intraoperative locations of extraarticular FAI. We found that extraarticular FAI was an uncommon source of impingement symptoms (approximately 4% of our overall population, 75 of 1765 patients during the study period), we suspect the diagnosis often

Table 6. Physical examination findings in three observed patterns of extraarticular FAI

Physical examination finding	Type I (anterior) (N = 47)	Type II (posterior) (N = 9)	Type III (complex) (N = 28)	p value
Anterior impingement sign				
Yes (%)	100	88	93	0.056
No (%)	0	12	7	
Posterior impingement sign				
Yes (%)	50	75	75	0.113
No (%)	50	25	25	
Flexion (°)	95 (90, 95)	100 (98, 103)	95 (90, 100)	0.138
Internal rotation at 90° (°)	15 (10, 20)§	40 (30, 55)§	15 (10, 30)§	0.002*
External rotation at 90° (°)	60 (45, 70)‡	40 (30, 65)	40 (20, 50)‡	< 0.001*
External rotation extension (°)	70 (55, 75)†	48 (35, 65)	40 (20, 60)†	< 0.001*
Internal rotation extension (°)	15 (5, 30)	40 (15, 48)	15 (5, 33)	0.058
Abduction	25 (20, 30)	30 (18, 33)	25 (15, 30)	0.532

All continuous variables presented as median [first quartile, third quartile]; *$p < 0.05$; †$p < 0.001$ anterior versus complex extraarticular FAI; ‡$p < 0.001$ anterior versus complex extraarticular FAI; §$p < 0.001$ posterior versus anterior extraarticular FAI, $p = 0.018$ posterior versus complex extraarticular FAI; FAI = femoroacetabular impingement.

was missed (because more of these patients had prior hip surgery before the procedure that diagnosed the extraarticular impingement source), and patients undergoing surgery for extraarticular FAI were younger, more frequently female, and had previous surgery compared with an intraarticular FAI cohort. Preoperative ROM and femoral version on CT scan corresponded to the patterns of extraarticular FAI visualized intraoperatively.

This study has several limitations. Data are limited to what was recorded in the hip preservation registry. The diagnosis of extraarticular FAI is made by the operating surgeon and currently remains a predominantly clinical diagnosis. However, all surgeons in this study are content experts and perform a high volume of open and/or arthroscopic hip preservation procedures and have a standardized method of assessing these patients both pre- and intraoperatively. Cases at our institution are routinely presented at a multidisciplinary conference to decide the best consensus approach for a given patient's pathology. This minimizes surgeon bias in diagnosis and treatment of extraarticular FAI. CT scan measurements are performed by eight fellowship-trained radiologists, which may create some interobserver variation, although previous studies have shown excellent intra- and interobserver reliability of these measurements [3, 12, 13]. Extraarticular FAI in the native hip is a relatively new diagnosis, and future studies with long-term followup will be necessary to ascertain whether these procedures provide lasting benefit to this patient population.

Patients undergoing surgery for symptomatic extraarticular FAI were more likely to be younger, female, and undergoing revision surgery compared with a typical intraarticular FAI population. Limited studies describing extraarticular impingement as a source of pain in the native hip also suggest that female patients are at increased risk for this pathology. Torriani et al. [28] characterized symptomatic ischiofemoral impingement by MRI and found an exclusive female predominance in the nine patients examined. Case reports of extraarticular impingement also suggest a female predominance [2, 20, 30]. Sex-based differences in acetabular and femoral version in young patients with symptomatic hip pain may exist, and some studies suggest that female patients in this population have increased femoral and combined anteversion relative to male patients, although this may not be generalizable across all populations [4, 9, 16, 18, 27]. A CT-based simulation study by Nakahara et al. [18] suggested that increased femoral and acetabular anteversion in female patients resulted in decreased ROM until bony impingement in extension and external rotation relative to male patients. Females may have increased periarticular soft tissue laxity relative to male patients, and this may increase their risk of realizing the possibility of extraarticular impingement, especially in activities requiring high ROM such as dance and yoga [15]. Taken together, previous studies suggest morphologic differences exist in female patients, and these differences may help explain their increased risk of symptomatic extraarticular impingement.

Within the extraarticular FAI cohort, preoperative ROM assessment and femoral version on CT scan appeared to correlate with locations of extraarticular impingement seen intraoperatively. Type I or anterior impingement was associated with relative femoral retroversion and Type II or posterior impingement was associated with relative femoral anteversion. The presence of cam lesions and labral damage in a major proportion of patients suggests that intraarticular impingement coexists many times with extraarticular impingement. Three primary patterns of extraarticular impingement were seen in our cohort: anterior facet of the greater trochanter and/or intertrochanteric line on the anterosuperior acetabular rim and/or AIIS (Type I); posterolateral impingement of the greater trochanter or extraarticular femoral neck on the ischium (Type II); and global impingement of the greater trochanter and/or extraarticular femoral neck on the ischium and ilium, anterior/superior acetabular rim, or AIIS (Type III). Hip morphology, particularly femoral version, may help predict locations of extraarticular impingement. Nakahara et al. [18] found that increased femoral anteversion was associated with a predicted decreased ROM until ischiofemoral impingement using CT-based modeling. Siebenrock et al. [22] found that a valgus femoral neck-shaft angle with concomitant increased femoral anteversion is particularly predisposed to posterior extraarticular impingement. We did not find an association of coxa valga with ischiofemoral impingement; however, the association between increased anteversion appears consistent with our findings. Greater trochanteric impingement with the ischium in external rotation may create a fulcrum effect, levering the femoral head anteriorly in the acetabulum, resulting in anterior labral tears and subsequent cartilage injury [22]. This finding would support a contre-coup mechanism of ischiofemoral impingement that results in anterior intraarticular injury. In a few patients we were able to visualize anterior subluxation of the femoral head with trochanteric femoral impingement as the hip was externally rotated. In these patients, the anterior labral was hypertrophic and torn from the acetabular rim. In contrast to the ischiofemoral impingement group, patients with anterior impingement in our study had increased rates of cam lesions and relative femoral and acetabular retroversion. These patients present with a predominantly anterior facet of the greater trochanter and AIIS impingement. The complex impingement group typically had more severe deformities such as those seen in Legg-Calvé-Perthes with prominence of the greater trochanter, poor offset, and femoral head deformity. These patients radiographically also had increased anteversion relative to the anterior impingement group; however, their more complex proximal femoral deformity also created anterior impingement. These findings are consistent with Tannast et al. [26], who found multidirectional decreased amplitudes of hip ROM in patients with Legg-Calvé-Perthes with extraarticular impingement locations predicted both anteriorly and superiorly on the acetabular rim and posteriorly on the ischium. We did not see any cases of lesser trochanteric impingement in our study population, and this entity may be less common than other types of extraarticular impingement [8].

Extraarticular FAI is an uncommon source of impingement symptoms. We suspect the diagnosis often is missed, because more of these patients had prior hip surgery before the procedure that diagnosed the extraarticular impingement source. Symptomatic extraarticular FAI seems more common in younger, female patients. Many patients had concomitant intraarticular impingement, suggesting a high index of suspicion must be kept to properly identify patients with extraarticular impingement and avoid the frequency of revision surgery we saw in this cohort. Femoral version and preoperative ROM corresponded with intraoperative locations of impingement pathology in the extraarticular FAI cohort. Future studies with longer and more complete patient followup will be necessary to ascertain whether these procedures provided lasting benefit in patients with extraarticular FAI. Additionally, improvements in preoperative identification of extraarticular FAI are critical to minimize unnecessary surgery in this challenging group of patients.

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